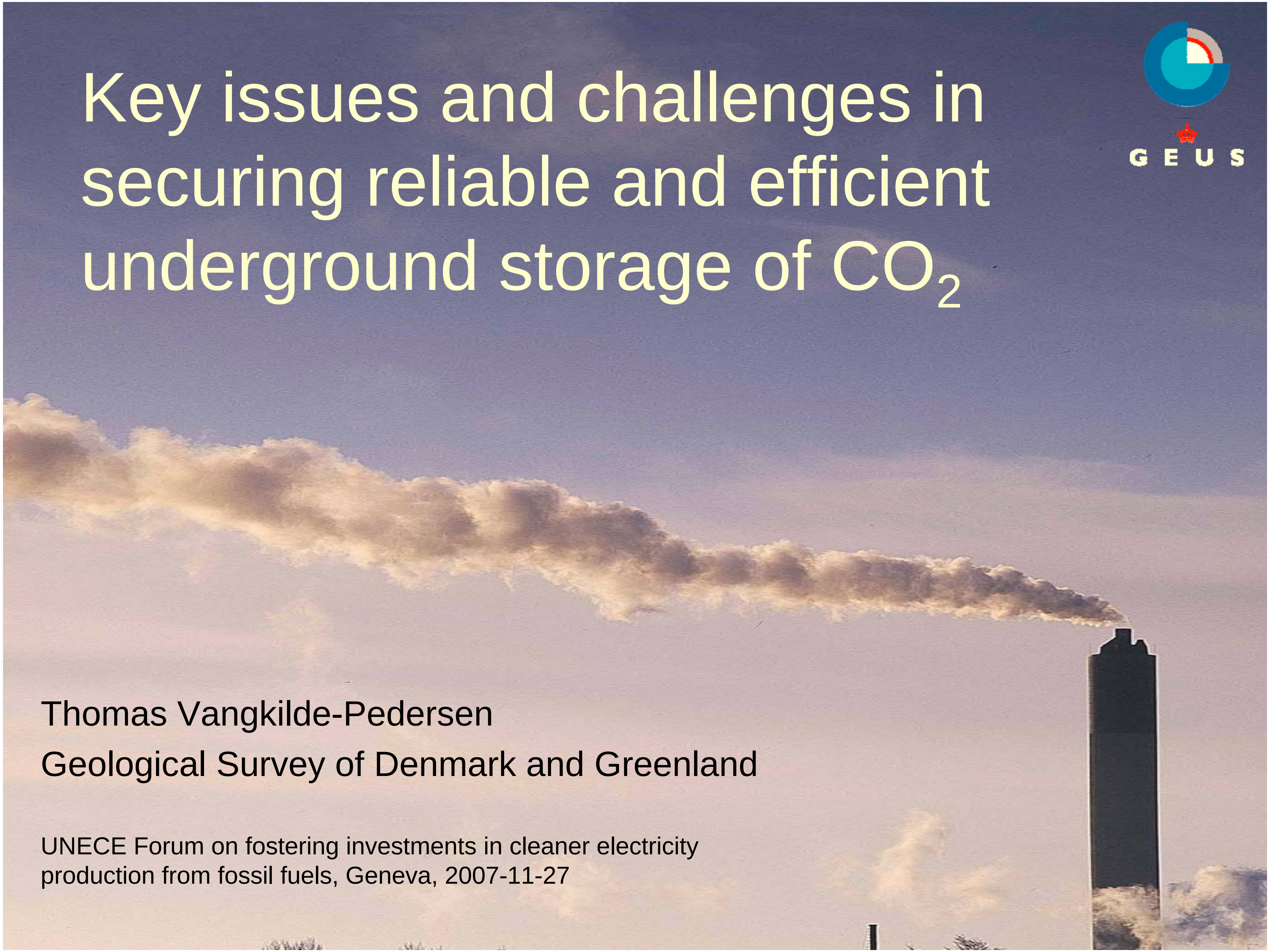


Key issues and challenges in securing reliable and efficient underground storage of CO_2

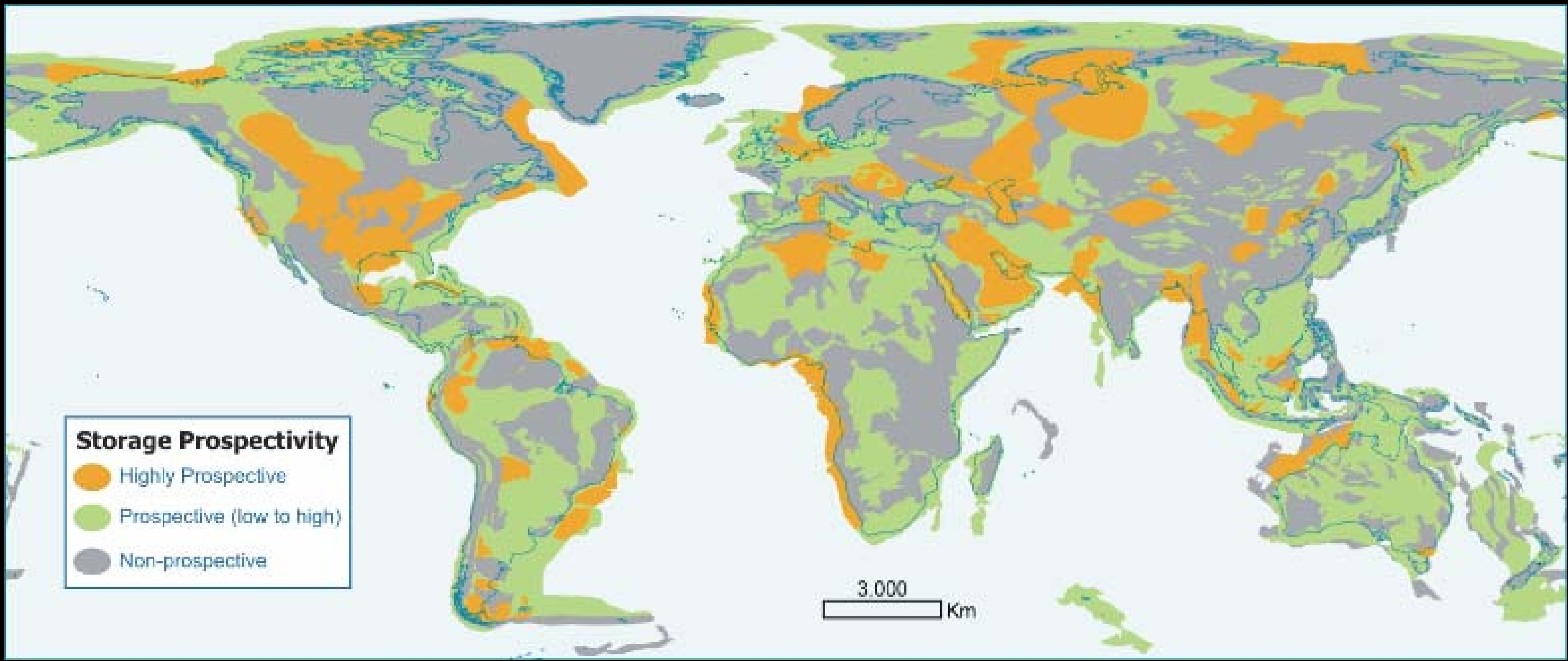
Thomas Vangkilde-Pedersen

Geological Survey of Denmark and Greenland

UNECE Forum on fostering investments in cleaner electricity production from fossil fuels, Geneva, 2007-11-27


Storage capacity estimation
Site selection & characterization
Safety - site monitoring
Courtesy: Vattenfall AB

World map of CO_2 storage prospectivity



Highly Prospective

Prospective – High to Low

Non-Prospective

- From Bradshaw & Dance 2004

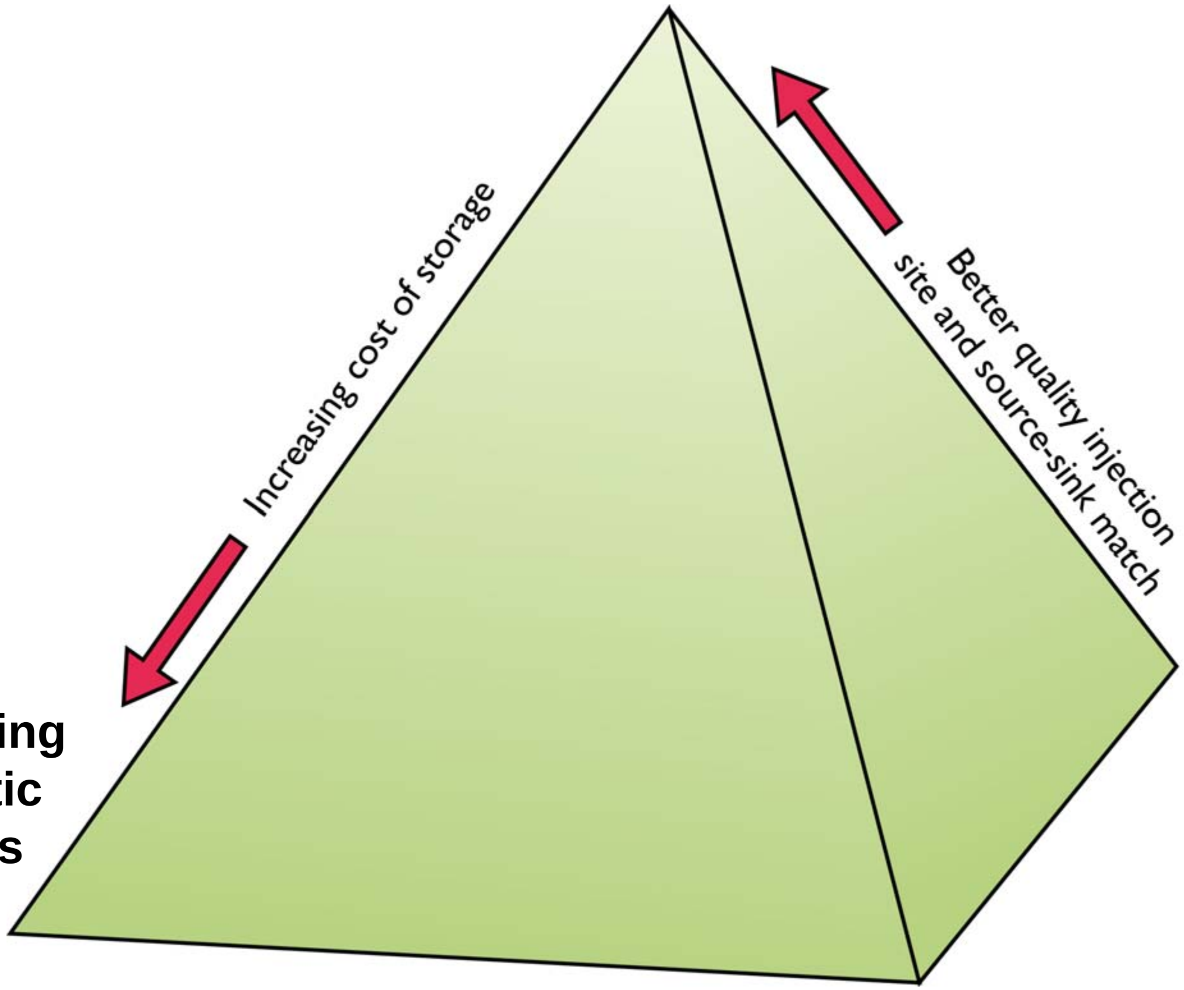
Assessment Scales and Resolution

- **Country**: high level, minimal data
- **Basin**: identify and quantify storage potential
- **Regional**: increased level of detail, identify prospects
- **Local**: very detailed, pre-engineering site selection
- **Site**: engineering level for permitting, design and implementation

Note: Depending on the size of a country in relation to its sedimentary basin(s), the order of the top two or three may interchange

• **From Stefan Bachu, CSLF, 2007**

CO_2 storage potential pyramid



Lower

<u>Theoretical</u> capacity including large uneconomic/unrealistic volumes: regional estimates without storage coefficient

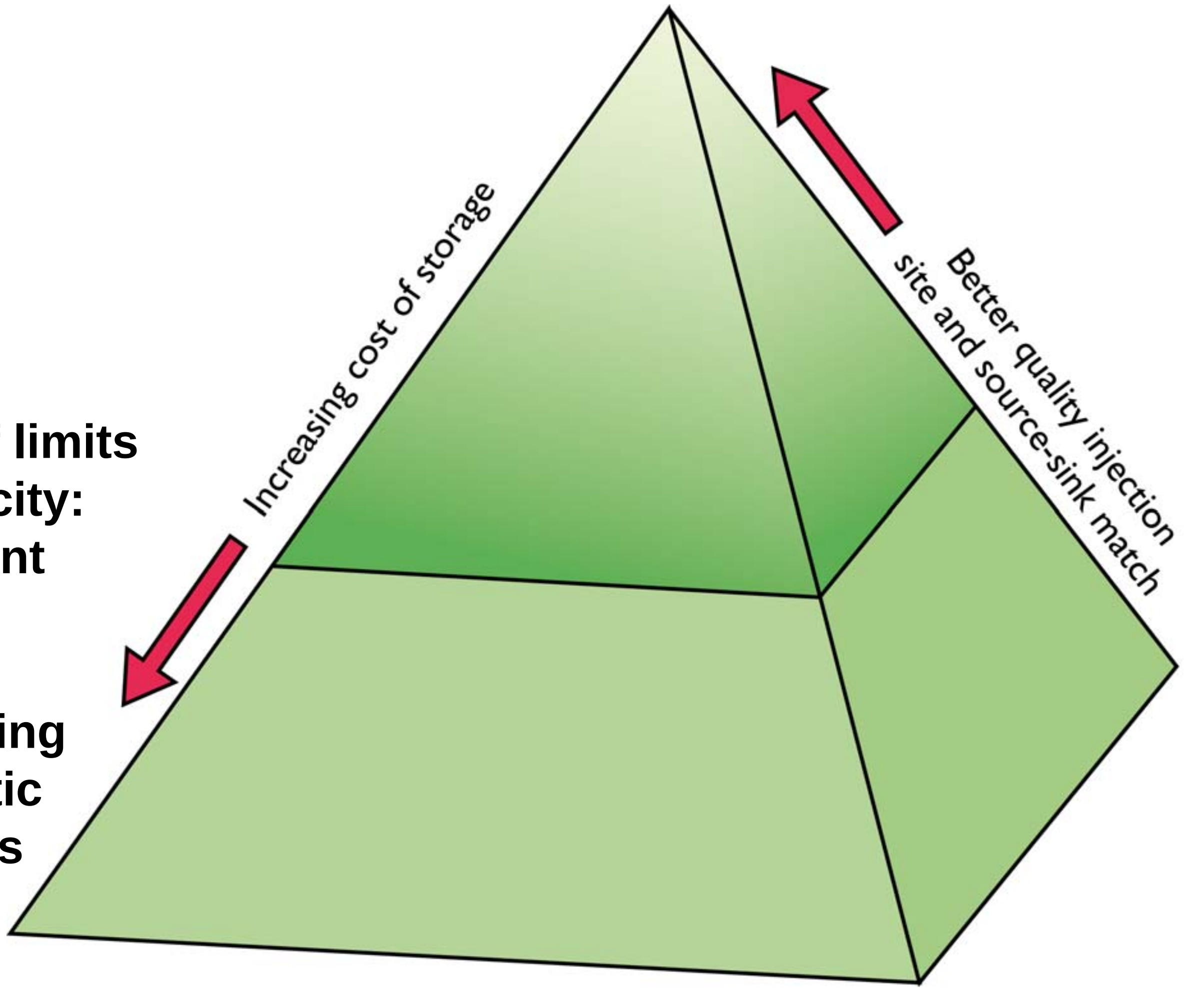
CO_2 storage potential pyramid

Middle

Effective capacity with technical/geological cut off limits applied to theoretical capacity: estimated storage coefficient

Lower

Theoretical capacity including large uneconomic/unrealistic volumes: regional estimates without storage coefficient



CO_2 storage potential pyramid

Upper

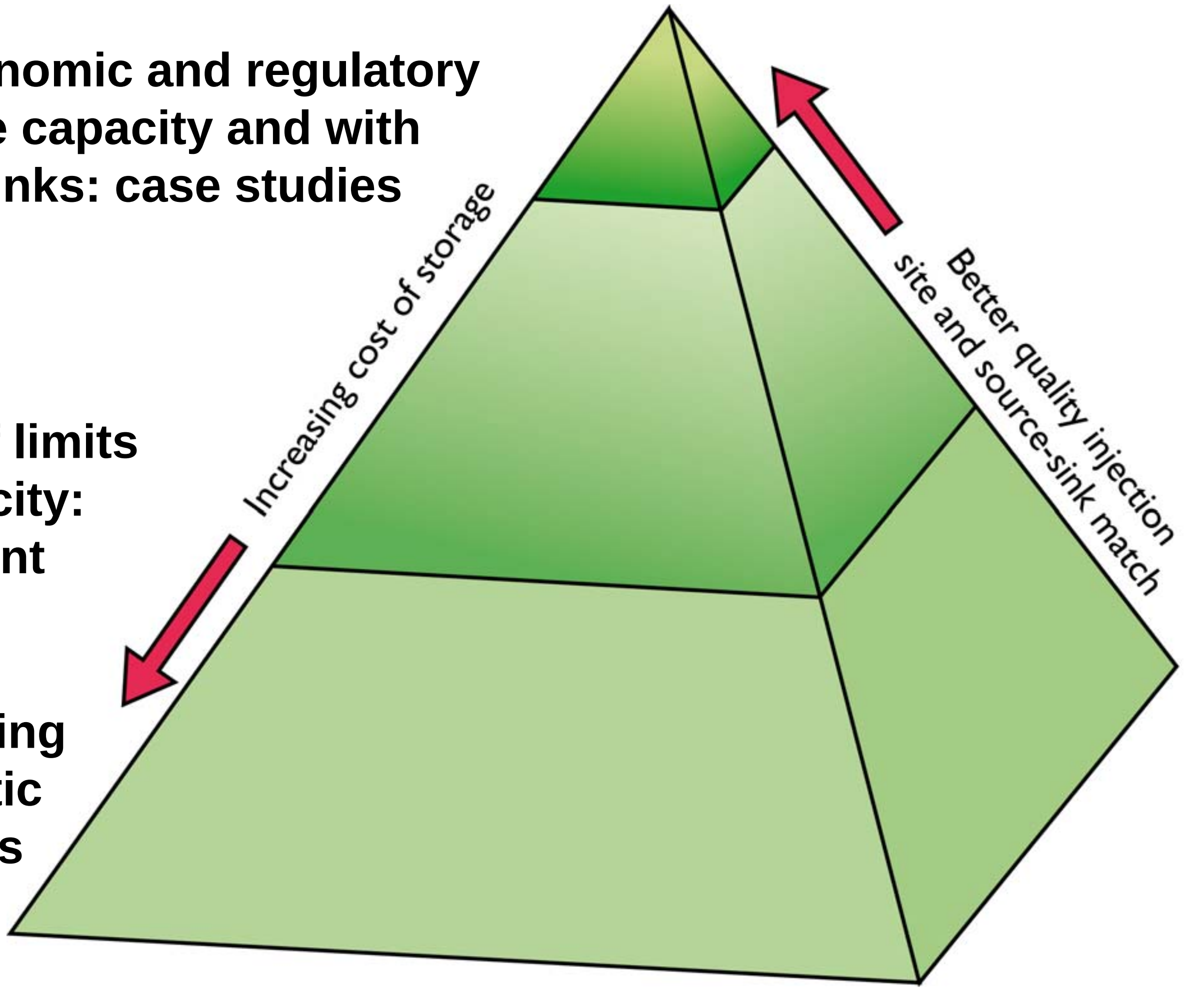
<u>Practical</u> capacity with economic and regulatory barriers applied to effective capacity and with matching of sources and sinks: case studies

Middle

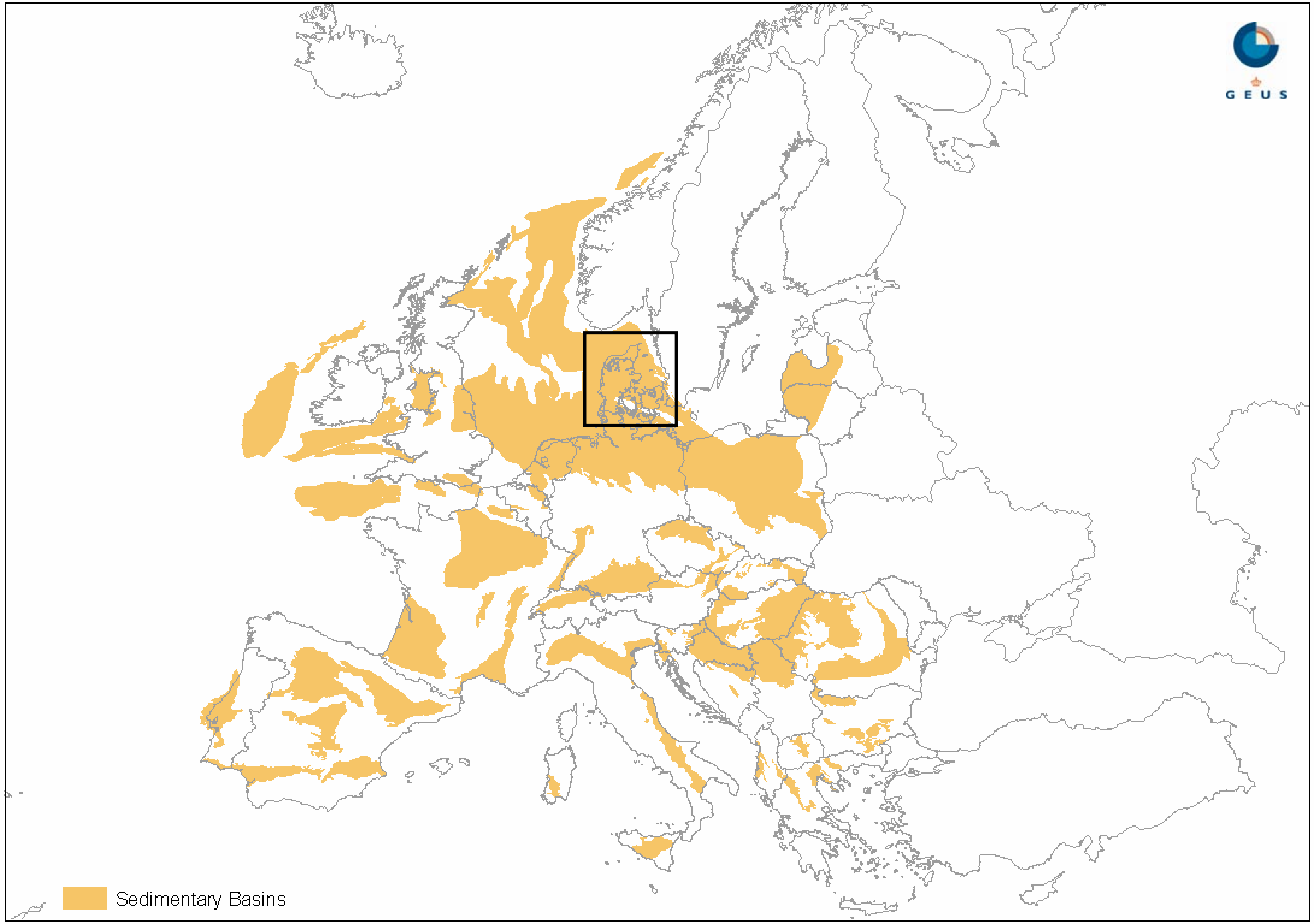
<u>Effective</u> capacity with technical/geological cut off limits applied to theoretical capacity: estimated storage coefficient

Lower

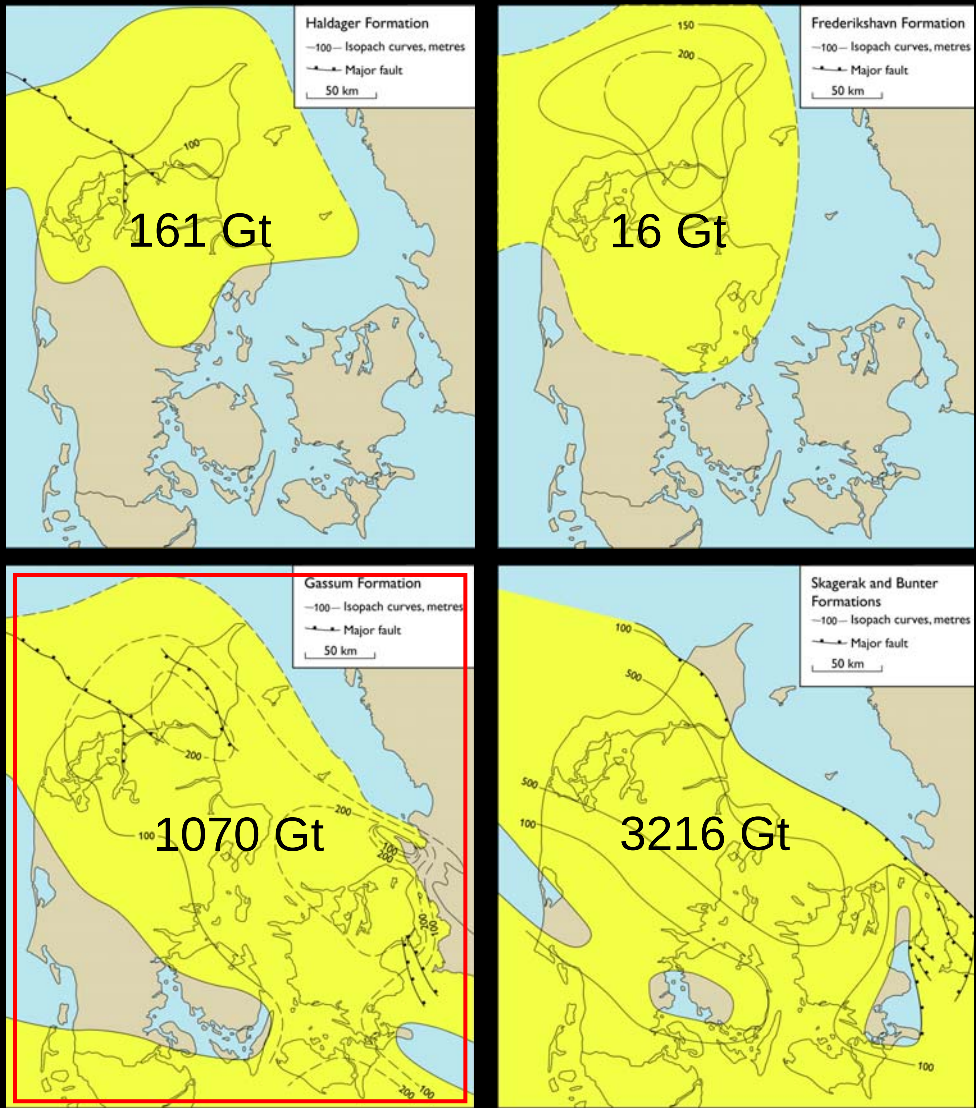
<u>Theoretical</u> capacity including large uneconomic/unrealistic volumes: regional estimates without storage coefficient

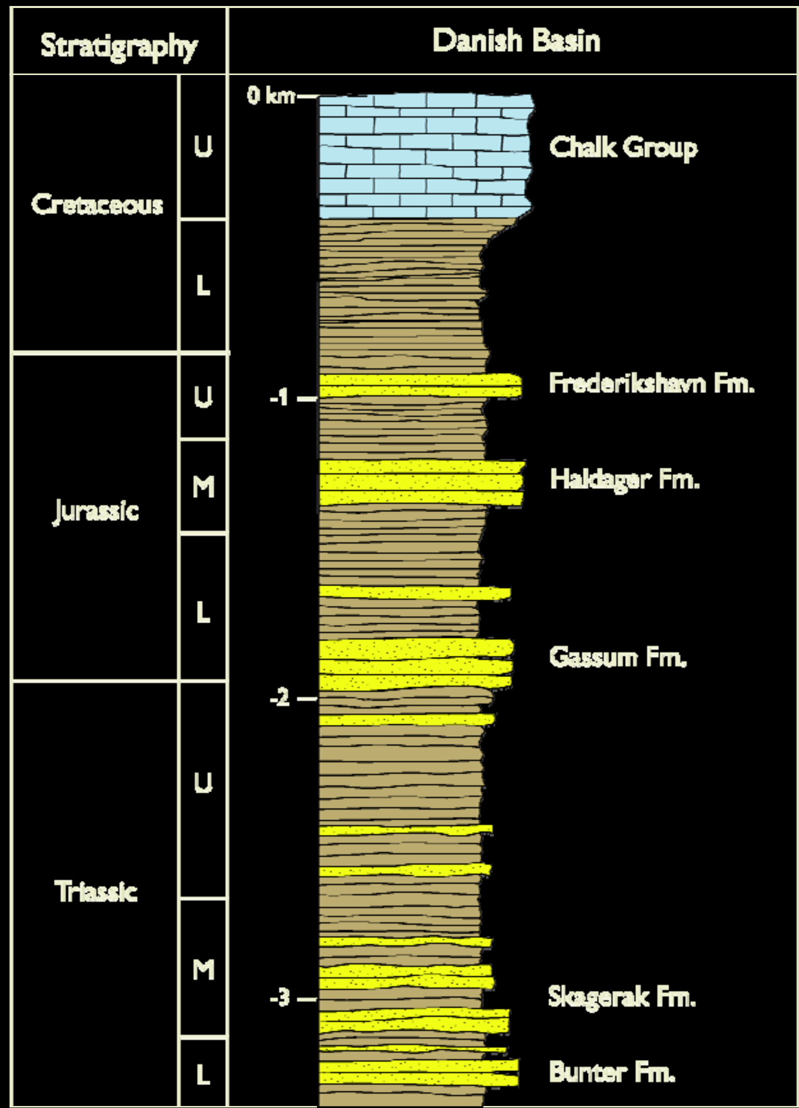


European map of CO_2 storage prospectivity

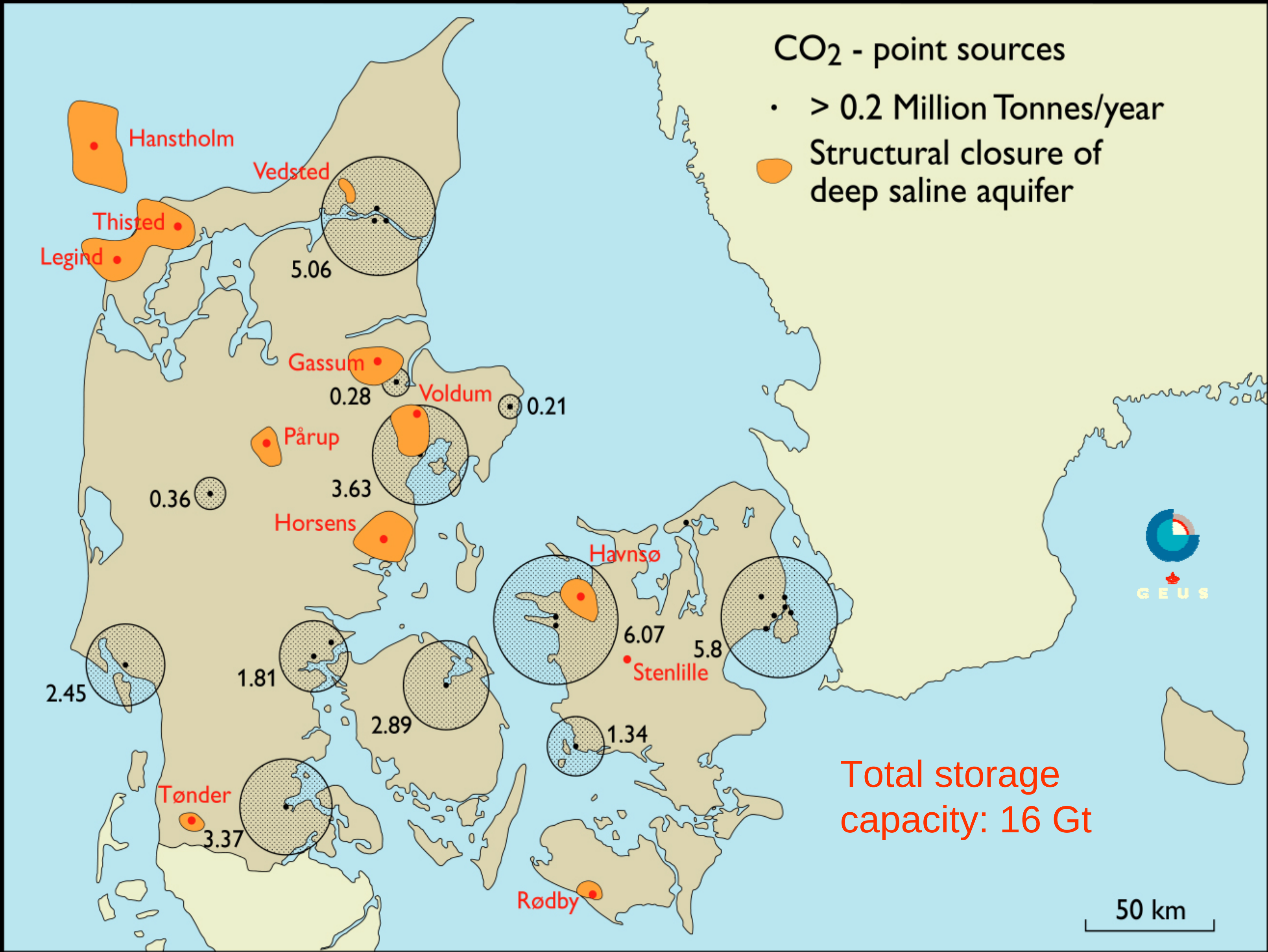


Regional map of CO_2 storage potential





Site specific CO_2 storage capacity



Components in a storage project

- Regional screening incl. capacity estimations
- Ranking of sites
- Site selection
- Site characterization
- Storage design and construction
- Injection operations incl. monitoring
- Site closure
- Post closure incl. monitoring

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Basic ranking and selection criteria

- Sufficient depth and storage capacity
  - supercritical CO_2 below 700-800 m (rule of thumb)
  - porosity may deteriorate below 2500-3000 m
  - trap type / areal extent / thickness
  - storage capacity

- Sufficient injectivity to be economically viable
  - permeability (as a rule of thumb > 200 mD)
  - reservoir lithology
  - heterogeneity of reservoir

- Integrity of seal
  - seal lithology and permeability
  - seal capillary pressure and pore entry pressure
  - faulting / tectonic activity / fracture pressure

What needs to be characterized

- Geometry of layers
  - traditional tools from petroleum exploration
- Geology
  - Lithology and geological reservoir models
- Petrophysics
  - permeability and porosity
- Mineralogy and geochemistry
  - interaction of CO_2 with fluids and rocks
  - Numerical simulations
- Stress regime and tectonic activity
- Reservoir and caprock properties
  - Numerical simulations

Why monitoring ?

- Monitoring will play a key role in demonstrating that storage performance meets appropriate standards

- It is highly unlikely that a careful chosen and managed storage site will leak, but the regulators are responsible for protecting the environment

- Monitoring shall take place for a variety of reasons:

  - Environmental reasons
    - for human health and safety
    - for protecting potable aquifers, habitats, biodiversity

  - Providing data to answer questions from public
    - leakage has been demonstrated to be a key public concern

  - Financial reasons
    - the market need confidence in the technology
    - storage accountable in future phases of the European ETS

Monitoring techniques

Monitoring buoys

Remote sensing

Soil gas

Microbiology

Geophysical methods

Laboratory experiments

Site monitoring

- Experience from industrial storage sites
  - Sleipner (4D seismic)
  - K12B (tracer injection)
  - InSalah (microseis)
  - Weyburn (soil gas measurements)

- Learn from fields with natural occurrence of CO_2
  - detect CO_2 migration pathways
  - test suitable monitoring techniques
  - study impact on humans and ecosystems

- Development of new metods
  - microbiology (vegetation, bacteria, etc. response to CO_2)
  - remote sensing (thermal imaging, vegetation stress)
  - offshore monitoring buoys (detecting CO_2 and CH_4)
  - resistivity, magnetometry, microgravity
  - natural tracers


Worst case scenario
is business as usual!
Need to get started now!